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Research Report 11 May 1963

Vigilance Performance as a Function of Task and Environmental Variables

by

Bruce O. Bergum and Donald J. Lehr

U.S. Army Air Defense Human Research Unit
Fort Bliss, Texas

Under the Technical Supervision of

The George Washington University
HUMAN RESOURCES RESEARCH OFFICE
operating under contract with
THE DEPARTMENT OF THE ARMY

HUMAN RESOURCES RESEARCH OFFICE
Office of the Director

30 April 1963

SUBJECT: Vigilance Performance as a Function of Task and Environmental Variables (VIGIL IV)

TO: [illegible]

1. The attached Research Report is transmitted for your information and retention.

2. This report describes 14 experiments conducted to compare the effects on vigilance of a group of task and environmental variables. The final experiment compared four combinations of the three most effective variables to determine the optimal conditions for maintaining peak operator efficiency in monitoring.

3. It is believed that this report will be of interest primarily to individuals and agencies conducting or having a direct concern with military personnel training in tasks involving vigilance (monitoring) situations.

Meredith P. Crawford

Meredith P. Crawford
Director

1 Incl
Research Report 11

VIGILANCE PERFORMANCE AS A FUNCTION OF TASK AND ENVIRONMENTAL VARIABLES

by

Bruce O. Bergum and Donald J. Lehr

Approved:

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Fort Bliss, Texas

The George Washington University
HUMAN RESOURCES RESEARCH OFFICE
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Task VIGIL IV

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BRIEF

Fourteen experiments were conducted to compare the effects on vigilance of paired and individual monitoring, high and low signal rates, rest periods versus continuous monitoring, knowledge of pretest performance, partial and complete knowledge of results of monitoring, monetary incentives, knowledge of vigil length, supervision by an officer, and false visual and auditory signals. Some of the experiments combined two or more of these variables; a final study compared four combinations of the three most effective variables.

The subjects were inexperienced National Guard trainees from the Army Training Center, Fort Bliss. During the experiments, they were seated at a table in a soundproof, artificially ventilated booth, either singly or in pairs, depending upon the specific experiment. Each booth was equipped with a circular display, 13 inches in diameter, consisting of 20 half-inch red lamps which were illuminated in sequence at a rate of 12 rpm. A "signal," for experimental purposes, consisted of the failure of a lamp to light in its normal sequence. The subjects indicated the occurrence of a signal by depressing a hand-held pushbutton. Both signals and responses were automatically registered on paper-tape recorders located in a central control area outside the booths.

The three most effective variables were determined to be multiple monitoring, monitoring with spaced rest periods, and supervised monitoring. In general, the data tended strongly to support a motivational interpretation of vigilance. In simple tasks, learning appears to be a trivial factor at best in the maintenance of detection performance. **The results for the optimization study suggest that significantly high levels of performance can be maintained over fairly extended time periods, with careful selection of conditions.**

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VIGILANCE PERFORMANCE AS A FUNCTION OF TASK AND ENVIRONMENTAL VARIABLES

INTRODUCTION AND BACKGROUND

This report summarizes the procedures, results, and conclusions for a series of studies on vigilance conducted at Fort Bliss, Texas, from January 1961 through June 1962.

The general objectives of VIGIL IV were to identify factors relevant to performance on a vigilance task and to develop methods and techniques for maintaining peak operator efficiency in vigilance situations. The specific purpose of the research reported here was to demonstrate the relationships between a series of task and environmental factors and vigilance performance.

An initial survey of the vigilance literature[1] indicated that a job-engineering approach to the problem of vigilance performance would have a reasonably high probability of success. The report of the survey discussed several hypotheses derived from theoretical considerations and cited empirical studies indicating four variables that have consistently significant effects on vigilance performance. These variables included the effects of variations in signal rate, group versus individual monitoring, the effects of interpolated rest periods, and the use of benzedrine.

With the exception of the benzedrine variable, the experiments in the present study were concerned with evaluation of the aforementioned factors, as well as a number of theoretically promising factors.

METHOD

Purpose

Fifteen experimental variables were studied. One class of studies included comparisons between multiple and single monitoring; paired and isolated monitoring at high and low signal rates; monitoring with and without rest intervals, at high and at low signal rates; a comparison of monitoring with rest intervals, paired monitoring, and a combination of the two conditions; and a comparison of transfer effects in going from high to low and from low to high signal rates, in terms of two different displays.

The purposes of this class of studies were to explore the influence of a task variable (signal rate) upon the output of multiple monitors; to determine the relative efficiency of using interpolated rest with isolated monitors versus continuous manning by paired and by isolated monitors; and to provide information concerning the feasibility of increasing

[1]Reference 2.

monitoring efficiency for tasks involving low or randomly fluctuating signal rates by training with high, low, or both high and low signal rates.

The second class of studies included comparisons of performance with 100 percent, 50 percent, and no knowledge of results; monetary versus no-incentive conditions; knowledge of vigil length versus no knowledge; and knowledge of pretest performance versus no knowledge. The purpose of this class of studies was to determine the motivating effects of rewards and of various forms and quantities of knowledge upon vigilance performance.

A third class of studies was concerned with the effects of false signals (signals that are discriminably different from normal signals) upon vigilance performance. This class included comparisons of three rates of false visual signals (12, 6, and 0 signals per hour), and one rate (6 signals per hour) of false auditory signals that the operator had to turn off. The purpose of these studies was to determine the effects of an increase in the level of task-induced stimulation upon vigilance performance.

The final basic study in the series compared the effects of observation by commissioned and noncommissioned officers on vigilance performance. The purpose of this study was to determine the motivating effects of supervision.

In addition to the basic studies, one other experiment was performed. This involved a laboratory comparison of four combinations of the three most effective variables among those tested. The purpose of this study was to determine an optimally effective, operationally feasible set of monitoring conditions.

Table 1 presents a summary of the control conditions for the 14 experiments.

Table 1
Control Conditions for Vigilance Experiments

Experiment	Test Periods		
	Signal Rate	Number	Length
I	24/hr.	3	30 min.
II	24/hr.	3	30 min.
III	6/hr.	3	30 min.
IV	24/hr.	3	30 min.
V	6/hr.	3	30 min.
VI	no specific control group		
VII	24 or 6/hr.	2	45 min.
VIII	12/hr.	1	60 min.
		1	90 min.
IX	12/hr.	1	60 min.
		1	90 min.
X	12/hr.	5	25 min.
XI	12/hr.	5	25 min.
XII	12/hr.	5	25 min.
XIII	12/hr.	5	25 min.
XIV	no specific control group		

Equipment

The equipment employed in this series of studies was essentially the same for all experiments. Minor modifications required for some of the studies are noted in the specific experimental descriptions.

Typically, four soundproof, artificially ventilated booths were employed. Each booth was equipped with a circular display, 13 inches in diameter, consisting of 20 half-inch red lamps which were illuminated in sequence for a period of approximately 1/10-second at a rate of 12 rpm. To the subject, the display normally presented the appearance of a single light moving in brief jumps around the periphery of the display. A "signal" for experimental purposes consisted of the failure of a lamp to light in its normal sequence. In this case, the apparently moving light appeared to the subject either to fail or to make an unusually large "jump." The subject was seated at a small table located directly facing the display, which was mounted vertically at his eye level on the rear wall of the booth. The room was illuminated by a shaded 25-watt frosted lamp mounted above and behind the subject.

The signal occurred on the display according to a preset program, and the subjects made responses by depressing a hand-held pushbutton. Both signals and responses were automatically registered on paper-tape recorders located in a central control area outside the booths. The control area and the four booths were interconnected by a two-way communications network.

The general experimental setup is illustrated in Figure 1.

Laboratory Vigilance Setup

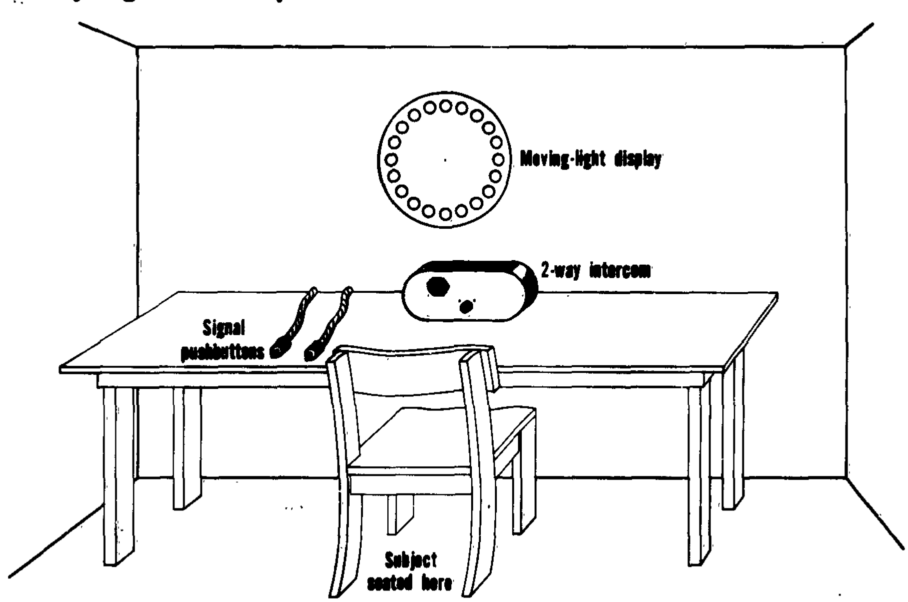

Figure 1

Subjects

Approximately 600 inexperienced National Guard trainees from the Army Training Center, Fort Bliss, served as subjects in this series of studies. Except for the requirements that they be between the ages of 18 and 26 years and have normal 20/20 vision (corrected), no effort was made to systematically select or assign the individuals participating in the studies. Before the experiment began, they were given instructions (see Appendix A) regarding the task they were to perform and a demonstration of the display in action.

RESULTS

Experiment I—Group vs. Individual Monitoring

Conditions. All subjects worked continuously for 90 minutes without rest. The 42 subjects in this experiment were randomly assigned to three groups of 14 each. Group I, the control group, consisted of individuals working in isolation; Group II consisted of pairs of individuals working in the same booth, with freedom to converse about anything but the occurrence of light failures (signals); Group III consisted of pairs of individuals working in the same booth with freedom to converse about anything, including the occurrence of signals. Separate measures were taken on the individuals in the pairs in Group II (paired monitoring), and a combined measure was taken for the pairs in Group III (multiple monitoring). The response measures were frequency of correct detections and response latencies. The signal rate was 24 signals per hour.

Results. Mean percentages of correct detections by the multiple (Group III) and single (Group I) monitors are presented in Figure 2. An analysis of variance of these data is given in Table B-1 (see Appendix B). Multiple monitoring resulted in the maintenance of a high level of detection performance over the entire 90-minute test period, whereas the single monitors detected significantly fewer signals during the second 30-minute period and continued at this level through the remainder of the task.

A second analysis compared performance of the individual members of the pairs of Group II (paired monitoring) with that of the isolated individuals (Group I). The percentages of correct detections by these groups at each time period are given in Figure 3. An analysis of variance for these data is presented in Appendix Table B-2. The difference between the groups was not significant, but both groups showed significant decrements over time. A comparison of the groups in terms of response latencies indicated no differences.

Experiment II—Pairing at High Signal Rate

Conditions. All subjects worked continuously for 90 minutes without rest. The 40 subjects were randomly assigned to two groups of 20 each. Group I consisted of individuals working in isolation;

Percentages of Correct Detections for Multiple and Single Monitoring

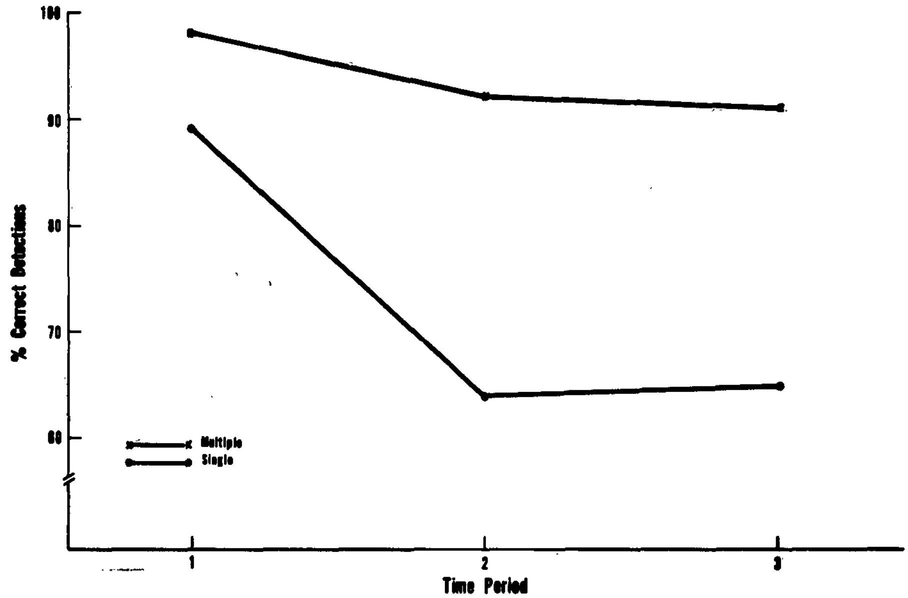

Figure 2

Percentages of Correct Detections by Isolated Monitors and by Individual Monitors Who Worked in Pairs

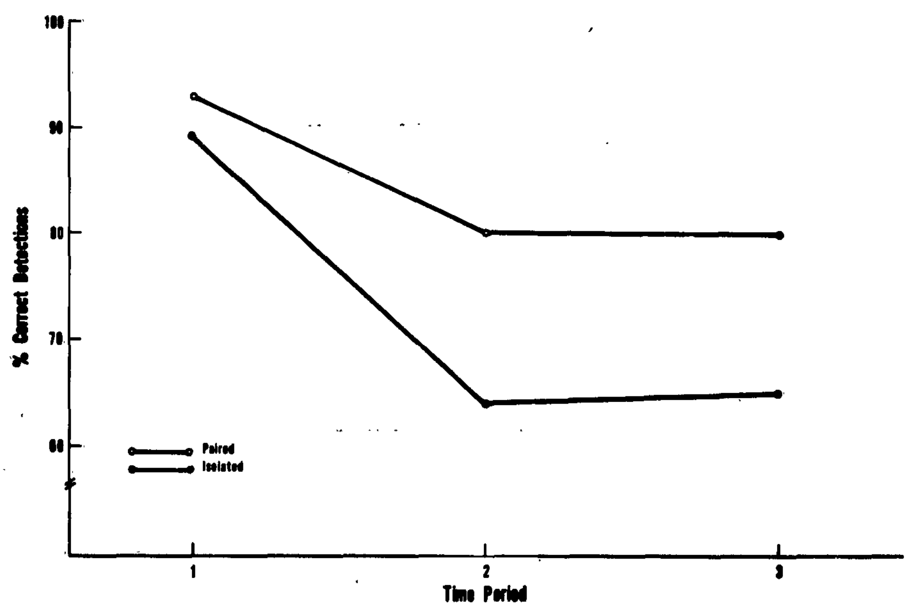

Figure 3

Group II consisted of pairs of individuals working independently in the same booth (paired monitoring), with freedom to converse about anything but the occurrence of signals (light failures). Separate measures were taken on all individuals in both groups. Signal rate was 24 signals per hour, and response measures were percentage of correct detections and response latencies.

Results. Figure 4 presents the mean detection scores for the two groups for each half-hour of the work period. Both groups showed a decline in performance over time, but the performance of the paired individuals was generally superior. However, a Kruskal-Wallis one-way analysis of variance indicated no significant difference between the groups.[1] A rank-order correlation ($r = .709$) between members of the 10 pairs of individuals working together was significant at the .05 level of probability. This could not be accounted for by experimental artifacts, which suggests that effective pairing may depend upon who works with whom. Analysis of the latency data showed no effects of any kind.

Percentages of Correct Detections by Paired and by Isolated Monitors (High Rate)

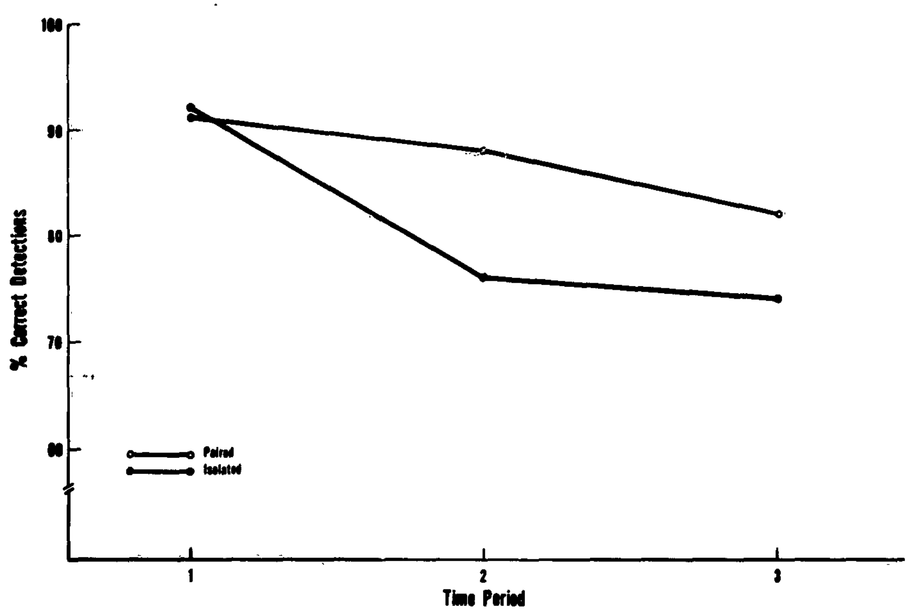

Figure 4

[1]The trials effect demonstrated in Experiment I indicated that this task and these general conditions will yield a significant vigilance effect in the control group. For this reason and because of the general similarity of control group results and conditions, the Kruskal-Wallis test was employed in Experiments II through VI, the interest in these studies being primarily in overall differences between control and experimental groups, and the Kruskal-Wallis test requiring no assumptions and being simpler to perform.

Experiment III—Pairing at Low Signal Rate

Conditions. With the exception of a signal rate of six signals per hour, the conditions for this experiment were identical with those employed in Experiment II.

Results. The mean percentages of correct detections by both groups for each half hour of the test period are presented in Figure 5. Both groups showed a decrement in performance over time, with neither group showing any marked superiority over the other. Statistical analysis indicated no group differences.

As in the preceding experiment, the correlation between performances of the paired individuals ($r = .773$) was significant ($p < .01$). Analysis of the latency data yielded no significant effects.

Percentages of Correct Detections by Paired and by Isolated Monitors (Low Rate)

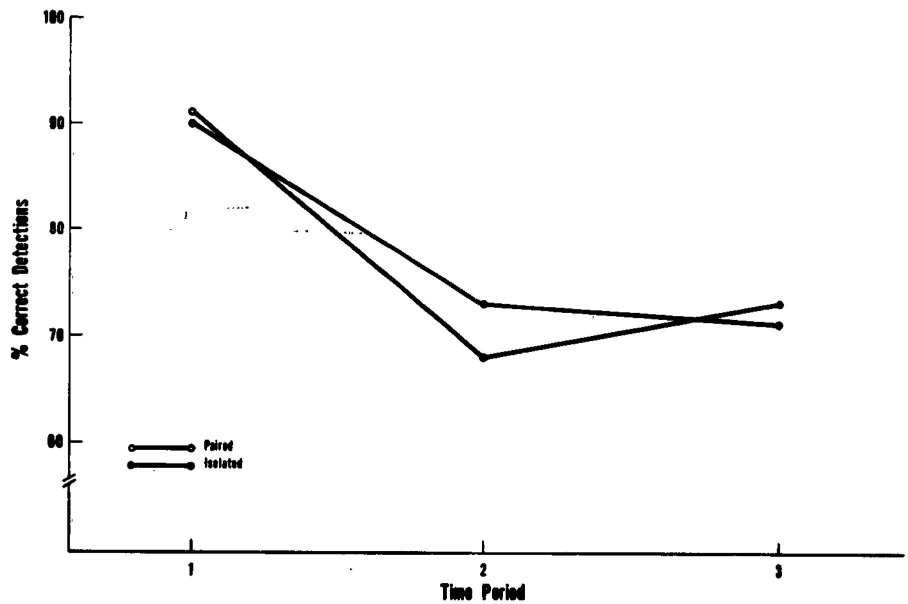

Figure 5

Experiment IV—Rest Periods at High Signal Rate

Conditions. Forty subjects were randomly assigned to two groups of 20 each. Group I worked continuously through the 90-minute period; Group II was permitted a 10-minute rest period outside the cubicles between first and second, and second and third monitoring periods. The signal rate was 24 signals per hour. Correct detections and response latencies were measured.

Results. The mean percentages of correct detections by both groups for each of the three test periods are given in Figure 6. The

Percentages of Correct Detections by Monitors With Rest Periods and by Control Monitors (High Rate)

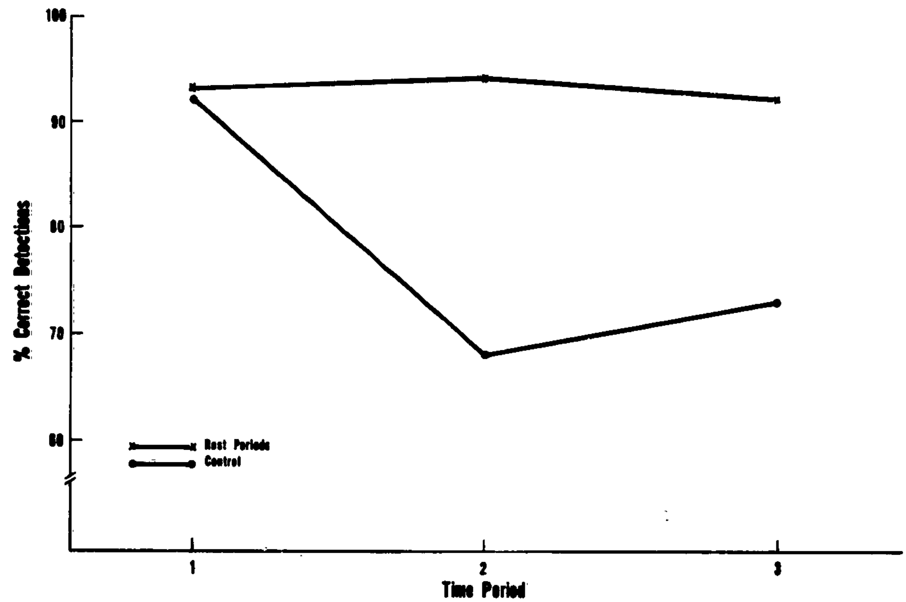

Figure 6

rest condition shows an almost constant high level of performance over the entire testing session, while the control condition shows a marked performance decrement that remains low during succeeding work periods.

A Kruskal-Wallis one-way analysis of variance indicated a difference between the groups significant beyond the .01 level of probability. Brief rest periods resulted in significantly superior detection performance. Analysis of the latency data indicated no significant effects.

Experiment V—Rest Periods at Low Signal Rate

Conditions. The conditions were identical with those employed in Experiment IV with the exception that the signal rate was six signals per hour.

Results. The mean percentages of correct detections by both groups for each of the three test periods is presented in Figure 7. The results are similar to those obtained in Experiment IV with a high signal rate. The rest condition shows an almost constant high level of performance over the full testing period, while the control condition shows a marked performance decrement over time.

Employing a Kruskal-Wallis one-way analysis of variance, the difference between groups was demonstrated to be significant beyond the .01 level of probability. Analysis of the latency data indicated no main effects, but there was a significant interaction between sessions and conditions ($p < .05$). The reason for this effect is not apparent.

Percentages of Correct Detections by Monitors With Rest Periods and by Control Monitors (Low Rate)

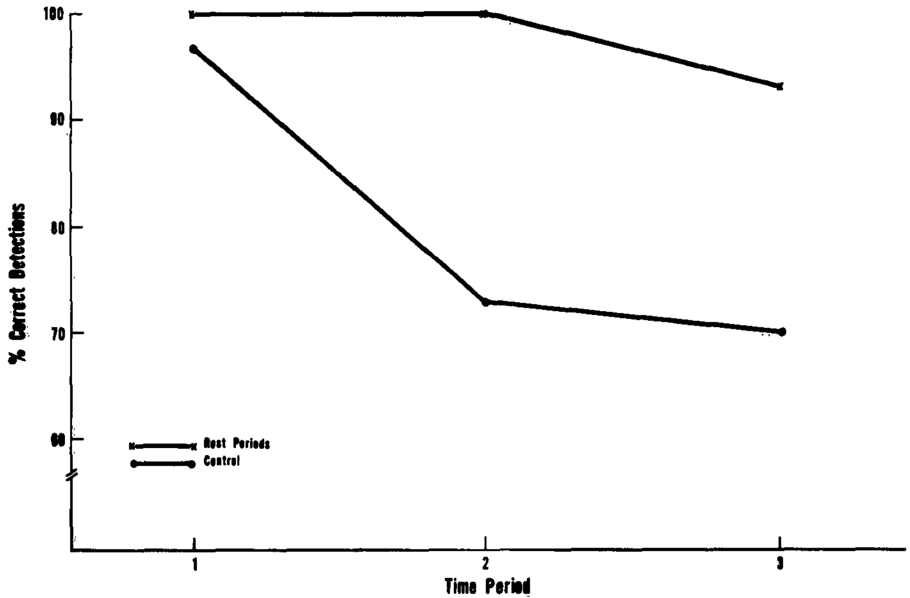

Figure 7

Percentages of Correct Detections by Monitors With Rest Periods, Paired Monitors, and Paired Monitors With Rest Periods

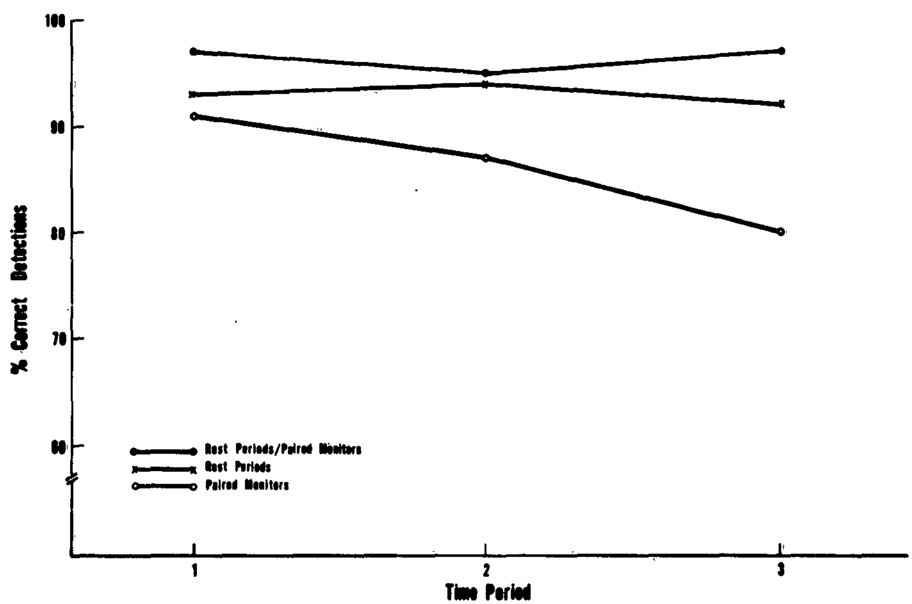

Figure 8

Experiment VI—Rest and Pairing Combined

Conditions. Sixty subjects were randomly assigned to three groups of 20 each. Group I consisted of paired individuals; Group II of individuals working alone, but with rest pauses; Group III of paired individuals with rest pauses. The signal rate was 24 signals per hour. The response measure was correct detections.

Results. The mean percentages of correct detections by all groups for each of the three monitoring periods are given in Figure 8. The combination of pairing with rest pauses yielded the highest over-all performance; rest pauses and paired monitoring followed in that order. However, none of these differences was statistically significant.

Experiment VII—Transfer Between Signal Rates

Conditions. In addition to the standard apparatus, two of the booths were equipped with a null-meter display. This display consisted of an ammeter with a pointer centered at zero which could vary through an angular range of 15° on either side of zero. Except when a signal was generated by the programmer, the pointer remained relatively stable about the zero point. Generation of a signal resulted in a clockwise deflection of the pointer through approximately 15° of rotation. Signals for both null-meter and light displays were simultaneously generated by the same programmer.

Combinations of two transfer and two display conditions were employed. In Condition I, the subjects monitored signals at a rate of 24 signals per hour, followed by a second session at a rate of 6 signals per hour. In Condition II, the subjects monitored first at a signal rate of 6 signals per hour, then at a rate of 24 signals per hour. Half the subjects in both transfer conditions worked with the light display and half with the null-meter display.

Eighty subjects were randomly assigned to the four conditions, with a total of 20 in each group. All subjects monitored through two 45-minute periods, with a 50-minute rest period outside the booths between sessions.

Results. The percentage of correct detections for the meter display was 94.9 and for the light display, 82.2. The difference between these results was highly significant statistically ($p < .003$). There was no significant transfer effect in going from high to low, nor from low to high signal rates for either display. In terms of the effect of signal rate per se, a high signal rate produced significantly superior performance on the light display only.

Experiment VIII—Knowledge of Results

Conditions. In addition to the standard apparatus, the booths were equipped with "hit-miss" displays. These displays consisted of two backlighted indicators mounted side by side in the center of the circular light display. When lighted, one indicator glowed green for a correct response; the other glowed red when a signal was missed. These

indicators were controlled by separate pushbuttons at the experimental control center and were appropriately activated by the experimenters for the two groups given knowledge of results.

The 60 subjects were given a 20-minute pretest on the apparatus, followed by a 10-minute rest and instruction period in the booths, and then by a 60-minute monitoring session in which the 20 subjects in each of the three groups performed according to their specific instructions. During the 60-minute differential-treatments session, the 20 control subjects received no feedback on results. The 20 subjects in the group given partial knowledge of results received information regarding their performance on 50 percent of the signals according to a random schedule. The 20 subjects in the group given complete knowledge of results received information regarding their performance on all signals presented. Signal rate was 12 signals per hour. After a second rest period of 20 minutes, all subjects monitored continuously under identical conditions for a period of 90 minutes.

Results. Figure 9 presents the mean percentages of correct detections by the three groups during the three 20-minute work periods of the differential-treatments session. The group receiving 100 percent knowledge of results yielded the best performance, followed in order by the partial-knowledge group and the control group. The differences were not statistically significant, although a significant ($p < .001$) overall decrement occurred. These results are contrary to the usual finding for this variable; they are in the expected direction, but suggest that this variable is not as general in its effects as had been thought.

The mean percentages of correct detections by the three groups for the three 30-minute identical-treatment time periods are presented in Figure 10. There were no significant differences in transfer between the groups. However, a significant over-all decrement ($p < .05$) did occur.

Experiment IX—Monetary Rewards

Conditions. The hit-miss indicator was not employed in this study. Otherwise, the apparatus and general procedures were identical with the preceding study. The 20 control subjects received no reward in either session. However, the 20 subjects in the monetary-reward group were told that at the end of the first session they would receive 20¢ for each signal they had correctly detected, but that 20¢ would be subtracted from their total for each failure to detect a signal. False responses were neither rewarded nor penalized. Each experimental subject could earn a maximum of $2.40 for the first session; they received no monetary incentive in the second session.

Results. Figure 11 presents the mean percentages of correct detections by the two groups during three 20-minute time periods of the differential-treatments session. Statistical analysis indicated a significant interaction between conditions and time periods and a significant over-all performance decrement. These results are given in Appendix Table B-3. A t test indicated that the reward group performed significantly better ($p < .01$) than the controls in the first period, but no better in the last two periods.

Percentages of Correct Detections for Knowledge of Results Experiment During Differential-Treatments Session

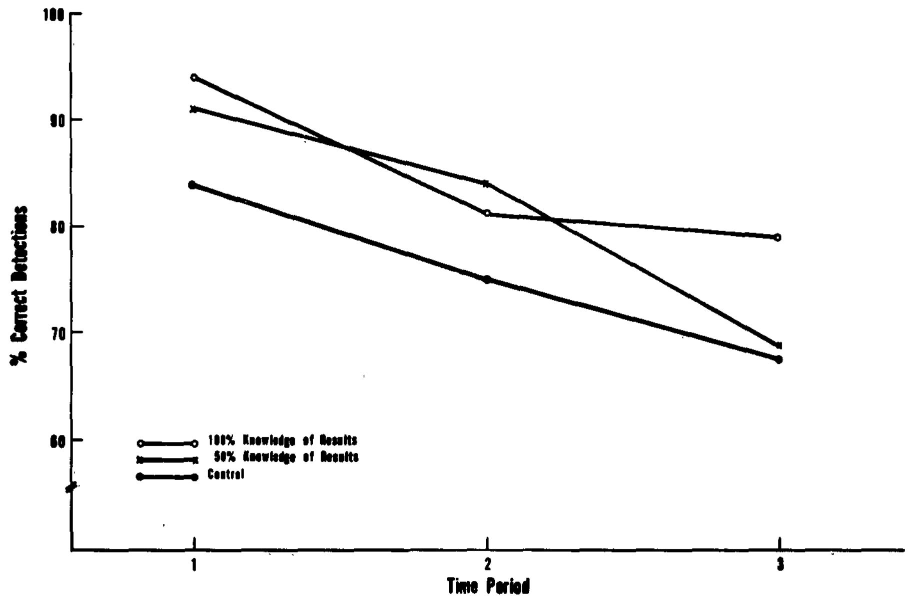

Figure 9

Percentages of Correct Detections for Knowledge of Results Experiment During Identical-Treatment Session

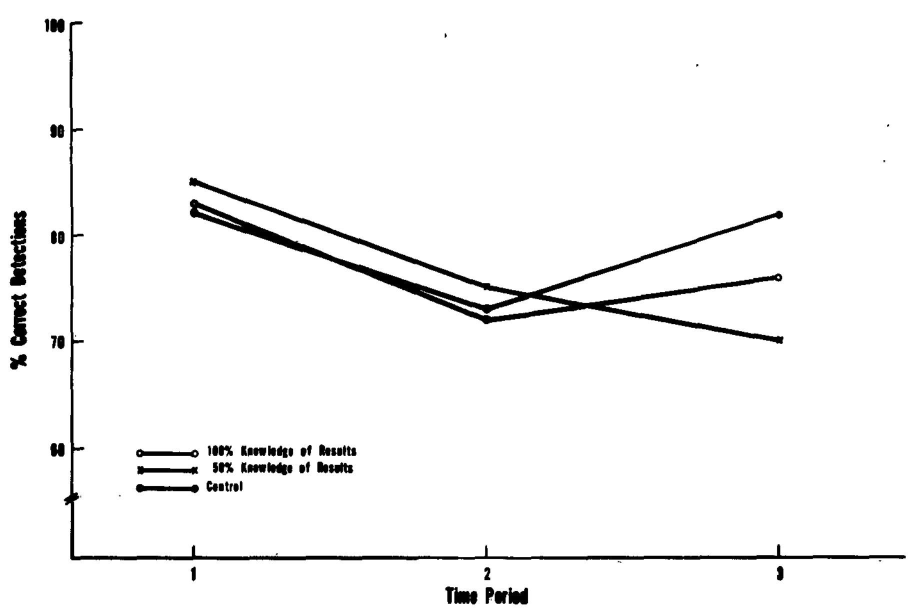

Figure 10

Figure 12 presents the mean percentages of correct detections by the two groups during three 30-minute time periods of the identical-treatment session. Statistical analysis indicated a significant interaction between conditions and time periods and a significant over-all performance decrement. These results are given in Appendix Table B-4. Performance of the reward group was at the same level as that of the controls in the first period, but was significantly poorer ($p < .01$ and $p < .05$) in the last two periods.

These results suggest that the facilitating effect of monetary rewards is short-lived and that the depressing effect on performance, observed when monetary rewards are removed, can be interpreted as resulting from a reduction in the motivational level of the reward group.

Experiment X—False Visual and Auditory Signals

Conditions. The apparatus was identical with that employed in the preceding studies. In this experiment, the hit portion of the hit-miss indicator was employed as a discriminably false visual signal indicator. In addition, a tone generator was located in the central control area, with associated earphones in each booth. Tones and visual false signals were automatically initiated by the central programmer. Signal rate for the false signals was 12 per hour; true signals were also given at a rate of 12 per hour.

All subjects were given a 20-minute pretest on the apparatus, followed by a 20-minute rest and instruction period, and then by a continuous monitoring session of 135 minutes. During the continuous monitoring session, the 20 control subjects received only true signals. The experimental subjects were randomly assigned to three groups of 20 each. Group I was required to respond in the normal way to discriminably false visual signals randomly interpolated among the true signals, at a rate of 12 signals per hour. Group II responded to discriminably false visual signals randomly interpolated among the true signals at a rate of 6 signals per hour. Group III was required to terminate a randomly interpolated, intense auditory signal (6 signals per hour) by making the visual response with the pushbutton.

Results. The mean percentages of correct detections of true signals by the four groups are presented in Figure 13 in five time periods. Analysis of these data indicated no differences between groups, but a highly significant ($p < .01$) over-all performance decrement. These results are presented in Appendix Table B-5. Contrary to findings of earlier studies in the literature, the experimental groups tended to perform somewhat more poorly over all than did the control group. Detections of false signals were not included in the analysis.

Experiment XI—Knowledge of Vigil Length

Conditions. The apparatus was identical with that employed in the preceding studies. Signals were presented at a rate of 12 per hour. All subjects were given a 20-minute pretest on the apparatus, followed

Percentages of Correct Detections by Reward and Control Groups in Differential-Treatments Session

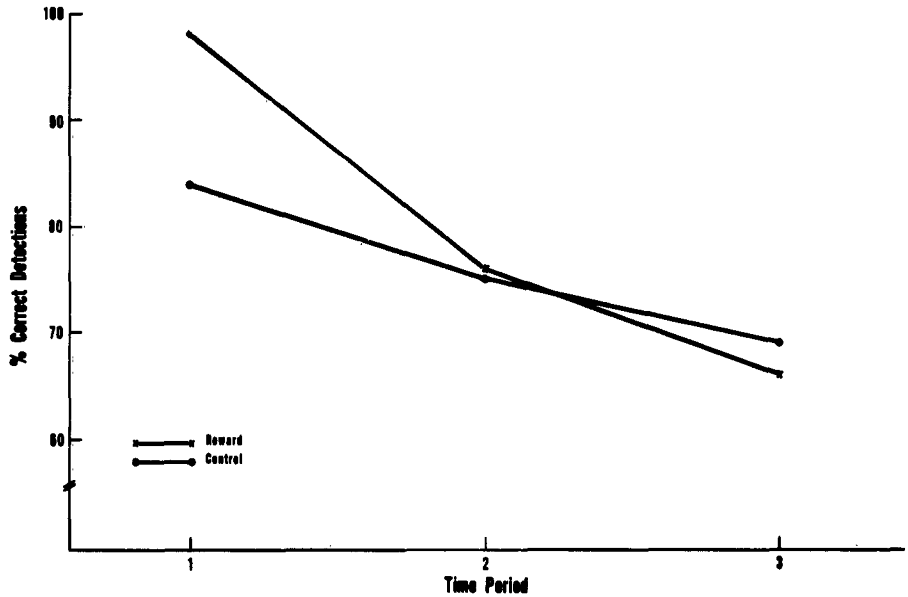

Figure 11

Percentages of Correct Detections by Reward and Control Groups in Identical-Treatment Session

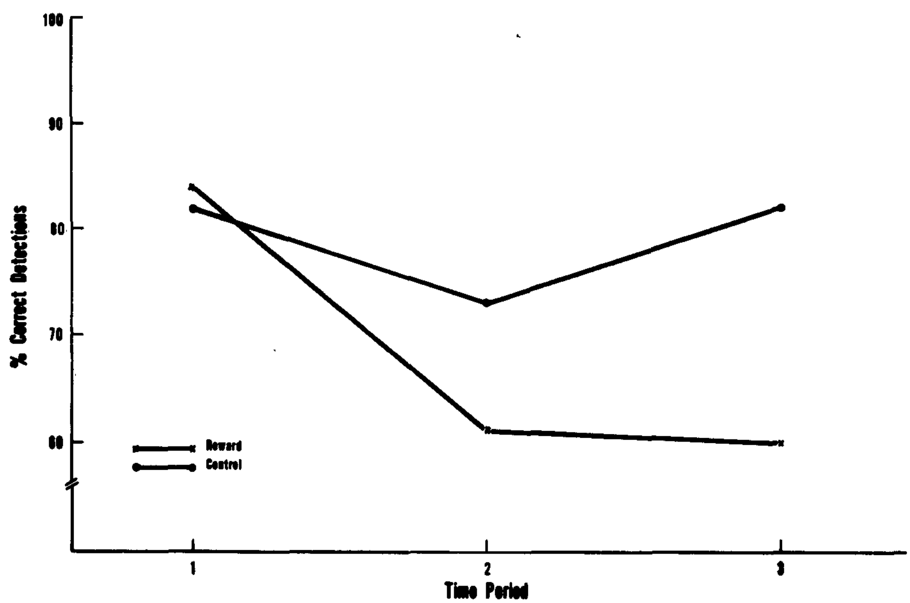

Figure 12

Percentages of Correct Detections of True Signals by the Three False-Signal Groups and the Control Group

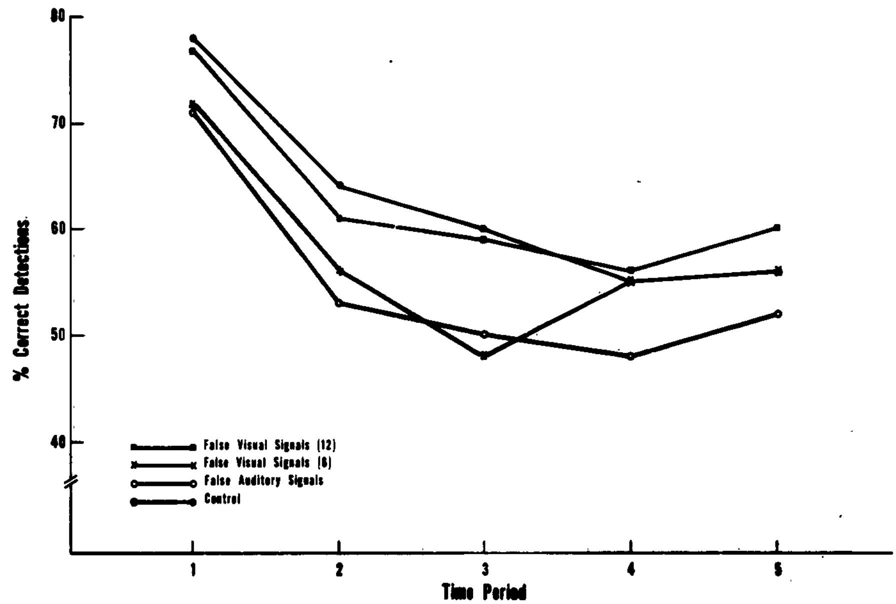

Figure 13

by a 20-minute rest and instruction period, and then by a continuous 135-minute monitoring session. The 20 experimental subjects were given information regarding the exact length of the monitoring session. This group was allowed to wear, or was provided with timepieces and was encouraged to make use of them during the session. The 20 control subjects deposited their timepieces with the experimenters and were given no information pertaining to vigil length.

Results. The mean percentages of correct detections by both groups are presented in Figure 14 in five time periods. An analysis of variance of these data is given in Appendix Table B-6. This analysis indicated no significant over-all performance difference between conditions, but a significant ($p < .01$) effect for time periods.

Figure 14 shows a typical decremental function for the control group, with performance tending to level off in the final two periods. In contrast, the experimental group showed an 18 percent increase in detections between the fourth and final time periods. Statistical analysis of the detection score differences between the fourth and final periods for both groups indicated no change for the controls but a highly significant ($p < .01$) improvement for the experimental group. **These results suggest that knowledge of vigil length is an important variable in determining the occurrence of an end-spurt effect.**

Percentages of Correct Detections by Group Knowing Vigil Length and by Control Group

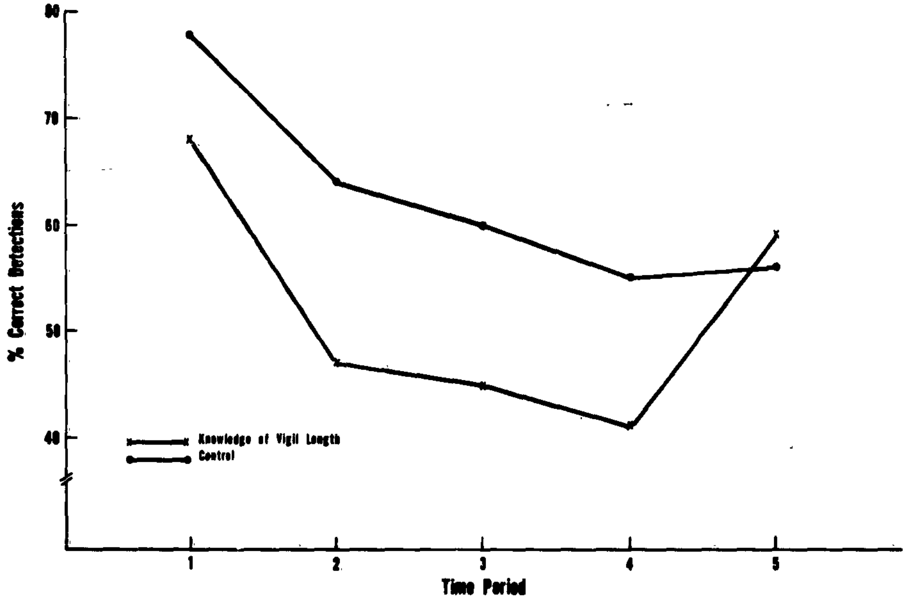

Figure 14

Percentages of Correct Detections by Group Given Knowledge of Pretest Performance and by Control Group

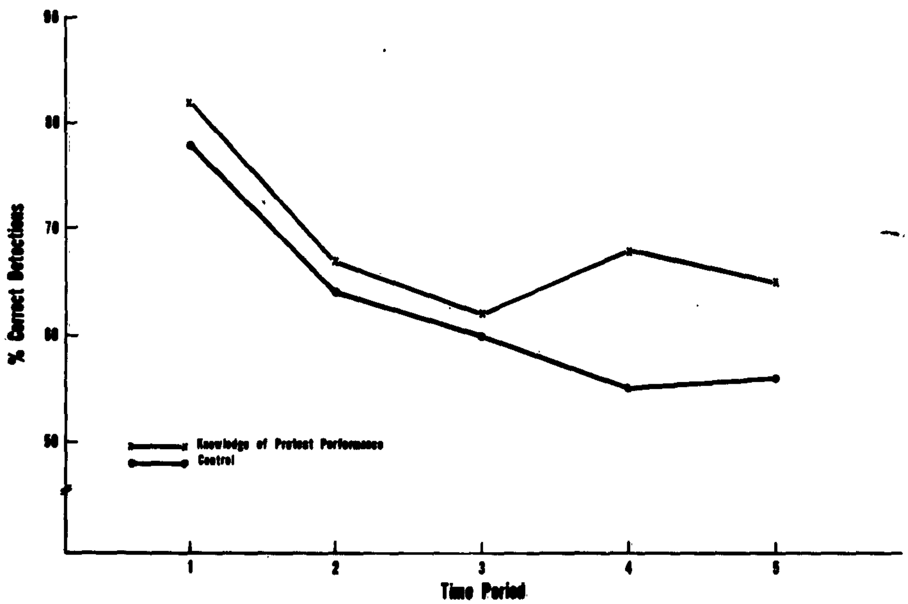

Figure 15

Experiment XII—Knowledge of Pretest Performance

Conditions. The apparatus and general procedures for this study were identical with those employed in the preceding study including a pretest period and 135 minutes of continuous monitoring. Signal rate was 12 signals per hour.

The 20 control subjects received no information. The 20 subjects in the experimental group were informed of their performances on the 20-minute pretest period before entering the booths for the 135-minute session. The percentage of correct detections on the pretest for each subject was read from an official roster to the group of four experimental subjects about to be tested.

Results. Figure 15 presents the mean percentages of correct detections by each group for each of five time periods. The experimental group showed slightly superior performance for all time periods. However, this superiority was not statistically significant. As indicated in Appendix Table B-7, the only significant effect on detections was that for time periods ($p < .01$). Both conditions resulted in a significant performance decrement over time.

In addition, correlations were performed between age and test performance for the members of both groups. The resulting correlations, corrected for coarse grouping, were .211 ($p > .05$) for the control group, and .452 ($p < .05$) for the experimental group. This finding suggests that the effect of pretest knowledge is some function of the general experiential or maturity level of the individual.

Experiment XIII—Supervised Monitoring

Conditions. The apparatus was identical with that employed in the preceding studies. Signal rate was 12 signals per hour. All subjects followed the same general procedure including a 20-minute pretest, followed by a 10-minute rest period, and then by 135 minutes of continuous monitoring in the booths.

The 20 subjects in the unsupervised condition were instructed to make themselves comfortable in the booths. They were told that for purposes of the research it was important that they detect as many signals as possible, but that they would be free to do anything they desired that would not interfere with this process.

The 20 subjects in the supervised condition were informed that from time to time a lieutenant colonel (or master sergeant) would visit them in the booths to observe their performance. The colonel and the sergeant each visited 10 experimental subjects during the course of the study. They entered the booths only during those intervals when signals were not programmed, and remained in the booths until at least one signal had occurred. Failures to detect signals were pointed out to the subjects by the observers and conversations were generally held to a minimum. Visits were made according to a prearranged schedule in which frequency and intervals between visits were counterbalanced across time periods. Each subject was visited approximately four times in the course of testing.

Results. The mean percentages of correct detections by each group for each of five time periods are presented in Figure 16. Both groups demonstrated decreases in performance between the first and second periods, with the control group showing an additional decrease in the third period. Performance tended to level off by the end of testing in both groups, but the supervised group was generally superior throughout all time periods. Statistical analysis indicated that both the difference between the groups and the decrement in performance were highly significant ($p < .01$). These results are given in Appendix Table B-8. A separate analysis of data from the supervised group in terms of the effects of the individual military observers was not significant.

Experiment XIV—Optimization Study

Purpose. The purpose of this study was to compare the relative effects of four combinations of variables on vigilance performance. Of the several variables studied in this program, three were selected that appeared to be (1) the most effective in maintaining high levels of monitoring performance, and (2) operationally most feasible. These variables were pairing, rest intervals, and supervised monitoring conditions.

Conditions. The apparatus was similar to that employed in the preceding studies. Two response pushbuttons were located in each of three booths and one response pushbutton was located in the fourth booth. Signal rate was 12 signals per hour.

Percentages of Correct Detections by Supervised and Control Groups

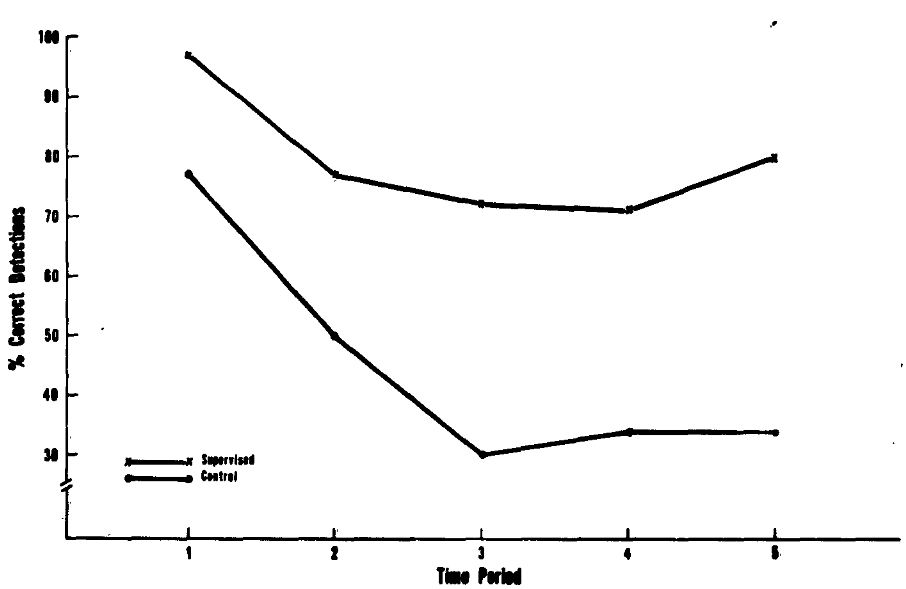

Figure 16

The first condition consisted of a combination of the supervised and rest variables. The 10 subjects in this condition served individually and were observed by a supervisor (master sergeant) according to a prearranged random schedule. Each subject had four 10-minute rest breaks during the continuous 150-minute period.

The second condition consisted of a combination of the supervised and pairing variables. In this condition, performance was measured in terms of system output (multiple monitoring) rather than individual performance. The 20 subjects in this condition were observed by a supervisor (master sergeant) according to a prearranged random schedule similar to that employed in the first condition. Subjects monitored continuously in pairs throughout the 150-minute testing period.

The third condition consisted of a combination of the pairing and rest-interval variables. The 20 subjects in this condition monitored in pairs, with each subject receiving four 10-minute rest breaks during the continuous 150-minute program. Rest periods were arranged so that one member of the pair was monitoring at all times.

The final condition consisted of a combination of all three variables. The 20 subjects in this condition monitored in pairs and were observed by a supervisor according to the schedule described earlier, with each subject receiving four 10-minute rest breaks during the 150-minute monitoring program.

Results. The mean percentages of correct detections by each group for each of four time periods are presented in Figure 17.

Percentages of Correct Detections by All Groups (Optimization Study)

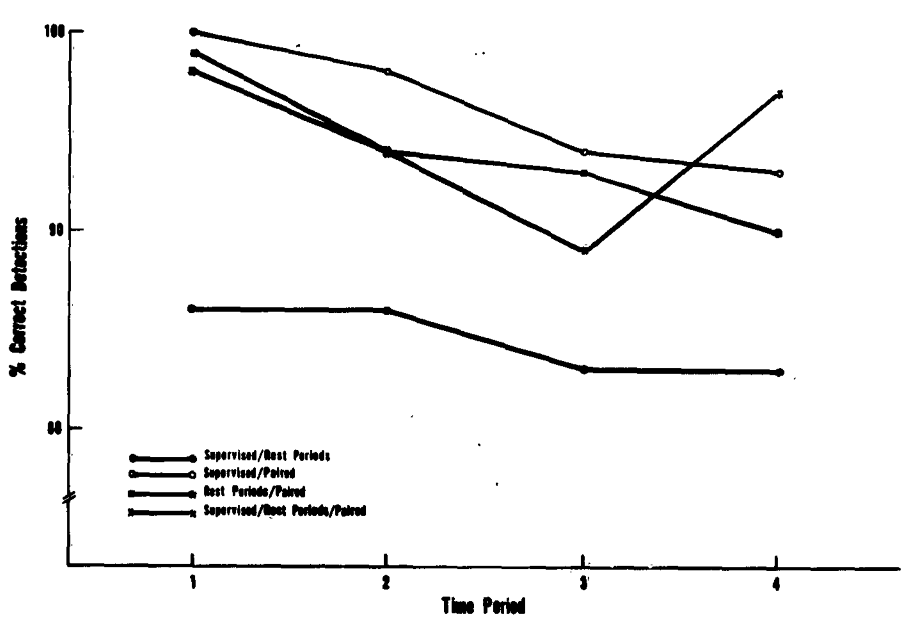

Figure 17

All groups tended to show a slight decrement in performance over time. The ordering of the groups in terms of over-all effectiveness was: supervised/paired, supervised/rest periods/paired, rest periods/paired, and supervised/rest periods. As indicated in Appendix Table B-9, while the small over-all decrement was significant, the differences between conditions was not significant. These results suggest that pairing, with some sort of supervision, will yield a consistently high level of performance over a rather extended time period, and that rest periods contribute little to this combination within the time period tested in this study. It should be noted, however, that during 40 percent of the testing period, only one individual was monitoring in the supervised/rest periods/paired condition because the rest periods did not overlap, and the combinatorial benefits of pairing were lost in this condition. This was also true of the rest periods/paired condition.

DISCUSSION AND SUMMARY

In general, the results indicated that multiple monitoring yields significantly improved detection performance for a system and, under some circumstances (high signal rates), may yield improved individual performance as well. In contrast, the effect of spaced rest periods was unambiguous. Regardless of signal rate, monitoring with rest periods consistently yielded high levels of individual performance and from the data it would appear that pauses of even briefer duration might prove equally effective.

The signficant correlation between performances of individuals working together but independently (paired monitoring) suggests some form of social or interpersonal interaction operating in this situation. This raises a number of questions concerning the nature or causes of this interaction. The possibility of illegal exchange of signal information can be ruled out on the basis of the pattern of responses and the random auditory monitoring by the experimenters. It is clear that the nature of this interaction is essentially stimulating since, at worst, paired performances were at least equal to those of the controls and, in general, tended to be better. Whether this stimulation stems from the arousal of competitive motivation or simply from the generally stimulating effects of conversation cannot be determined from the present data, but the results suggest a number of interesting research possibilities, including the relationships between a variety of personality variables, or syndromes, and susceptibility to the pairing effect.

The failure to demonstrate significant transfer effects as a function of different signal rates is not surprising. While a slight tendency was observed in the predicted direction, the effect was minor at best. This is in line with the fact that no evidence of learning was demonstrated in any of the studies in which such effects could reasonably have been anticipated (those studies employing pretests, successive test periods after rest, or two-session studies).

Two points upon which expectancy theorists appear to place heavy reliance were of small consequence in this series of studies. Response

latencies were demonstrated to be significantly related to detection probabilities in only one instance. Again, signal rate was demonstrated to be a significant variable in only one of the several studies in which it was manipulated. This study (transfer) involved correlated measures on a very large N, suggesting that signal rate is a relatively minor variable in vigilance.

The finding that little decrement occurred with the meter display, with the false visual signals, and with the false auditory signals supports the suggestion that, in defining vigilance, the signals be qualified as being near threshold. When intense, prolonged, or otherwise clearly discriminable stimuli are involved, very little if any performance decrement can be observed. This effect is in line with an "arousal" interpretation of vigilance, since arousal theory is essentially a theory of thresholds.

The failure to demonstrate any significant effect due to knowledge of results is contrary to the usual finding, and suggests that the variable is somewhat less general in its effects than has ordinarily been indicated. The tendency was toward better performance, however, and it is worth noting that the group receiving knowledge of 50 percent of results performed very similarly to the group given knowledge of 100 percent of results. This implies that under conditions where knowledge of results is effective the 50 percent condition might be as effective as the 100 percent condition.

The superior performance of the reward group in the first period of the differential-treatments session was as anticipated. The decline in performance to the level of the controls during the second and third periods of that session, however, indicates that the effect was short-lived. Of greater interest was the significantly poorer performance of the experimental group in the identical-treatment session, when rewards were no longer provided. These results suggest that the net effect of the withdrawal of rewards is to reduce the motivational level to a point lower than that of a group that has never had rewards. In short, the indiscriminate use of rewards may result in a net <u>loss</u> in detection proficiency.

Similarly, the performance of the group given knowledge of vigil length tended to be poorer than that of the controls over all. These results were of considerable theoretical interest and supported the hypothesis that—because of the self-stimulating characteristics of goal-oriented $\underline{r}_g$-$\underline{s}_g$'s—increases in the frequency and intensity of fractional anticipatory goal responses as termination of the task is approached would result in a general increase in the motivational level of the monitor, with a consequent increase in the probability of detection. This end-spurt improvement, however, was an increase <u>to</u> the level of the controls at the end of testing from a level well below that of the controls during the center portion of the session. Thus, while the end-spurt was theoretically predictable, the net effect of the condition was to reduce the over-all performance for this group. In any case, it should be noted that the results were equally predictable with either the Hull-Spence conditioning theory[1] or a combination of conditioning

[1]References 5 and 7.

and arousal theory. These results could not have been predicted by expectancy theory because expectancies are not attributed the motivational characteristics of $\underline{r}_g$-$\underline{s}_g$.

The results for the variable, knowledge of pretest performance, while showing no significant over-all improvement in performance, suggest that this variable could be significantly effective under some circumstances. As demonstrated in this study, the effectiveness of this variable appears to be related to the age of the subject; this suggests that a maturity factor is involved because, in general terms, chronological age is related to maturity. One characteristic of maturity is an increased appreciation of the consequences of behavior, which, in turn, implies an increased perceptiveness of and responsiveness to threat and the consequences of threat. In the present study, the operations employed to generate a condition of ego-involvement were of a subtly threatening nature and could well have been perceived as such by the more experienced subjects. Aside from speculations as to the cause, the fact that older subjects perform better under these conditions is of some practical significance because it implies that age might be of some value in the selection of operators.

The failure to demonstrate greater vigilance in the detection of true signals as a result of interpolating false signals is contrary to results reported in the literature. When considered in terms of the nature of the false signals employed in the present studies, however, the results become more understandable. The earlier studies employed either false signals that were indiscriminable from the true signals,[1] or signals in the same modality that were qualitatively discriminable but of similar intensity.[2] In the present studies, one condition employed an intense false signal in a different sense modality from that of the true signal; under the other two conditions, although in the same sense modality, the false signals were more intense by several orders of magnitude and were located in central, physically distinct positions. The present experiments were undertaken because it was suspected that the use of false signals might not, in fact, lead to facilitation in the detection of true signals, and the data bore out this suspicion.

In a sense, the false signals employed in these experiments constituted a condition similar to that in other studies in which a second, or time-shared task was employed. In such tasks (e.g., multiple-dial monitoring studies),[3] the increase in task complexity did not improve performance on either detection task, and did in fact tend to <u>reduce</u> over-all performance. In the present studies, although performance on the primary task tended to be reduced below that of the controls, a significant decrement did occur, which suggests that present conditions lie somewhere between the simple and multiple-dial tasks along a dimension of complexity. It is neither surprising nor inconsistent with the present results that those studies using arbitrarily designated real signals as false signals have resulted in improved detection of true

[1]Reference 4.
[2]Reference 1.
[3]Reference 6.

signals; operationally, such conditions are identical with an increase in a known, sometimes effective variable—signal rate. The present results do suggest that general statements regarding the effects of increased stimulation (activation hypothesis) are not valid when such stimulation results in increased task complexity.

The expectation that detection performance can be maintained at relatively high levels under supervised conditions was confirmed by the data. Of particular interest was the wide difference in performance between the experimental and control groups. This difference (46% in the final period) is even greater than that demonstrated with rest periods. While a significant decrement did occur in the experimental group, the poor performance of the control group suggests that, had the easier task employed in the earlier study (24 signals per hour, with a 90-minute monitoring period—Experiment IV) been employed in the present study, the supervised condition might have yielded a similar, nearly perfect performance.

If it is hypothesized that the supervised condition represents an extreme point along a continuum relating to the amount of threat represented by the presence of an observer or a second individual, then we would predict an ordering of such conditions in terms of the differences between control and experimental groups, with the supervised group showing the greatest difference. Comparison of the supervised study with a study by Fraser,[1] in which the experimenter was present during testing, and with the pairing study in this series yielded ratios between the errors made by the control groups and the errors made by the experimental groups which were ordered in the predicted direction. These ratios were: pairing, .689; experimenter present, .410; and supervised, .363. As might be anticipated, the Fraser results lay slightly closer to the supervised than to the pairing results.

The results for the optimization study were as anticipated and require no further discussion. They do suggest that, with a careful selection of conditions, significantly high levels of performance can be maintained over fairly extended time periods.

In general, the data tend strongly to support a motivational interpretation of vigilance. In simple tasks, or tasks in which the necessary discriminations have been well established, learning appears to be a trivial factor at best in the maintenance of detection performance.

[1]Reference 3.

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AND
APPENDICES

REFERENCES

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Appendix A

INSTRUCTIONS TO THE OPERATORS

You are going to spend most of the morning (afternoon) doing a very simple and rather tedious job. You will notice that the lights on the outer edge of this display come on in consecutive order and appear to be moving around in a circle. Now occasionally, and randomly, a light will fail to come on when it is supposed to. This is what the display looks like when a light failure occurs.

When you see that a light has failed to come on when it was supposed to, you are to press the hand button located on the top of your work table. Press the button only once and as soon as you have seen that a light failure has occurred.

You will be free to smoke, to change positions, or do whatever you want to do to make yourselves comfortable. The only thing we require of you is that you keep your eyes on the display and catch as many signals as you can.

Are there any questions?

Appendix B

ANALYSES OF VARIANCE OF EXPERIMENTAL DATA

The analysis of vigilance data presents a difficult statistical problem. Typically, the control groups show unusually large variances while, in contrast, under effective experimental conditions a large number of perfect scores is not an unusual observation. The net effect is both a restriction in variability and an artificially low mean for the experimental conditions. In combination, these factors (very large control variance and truncated experimental distributions) work against the demonstration of statistically significant differences. In the case of $\underline{F}$, for example, one factor tends to increase the denominator while the other tends to decrease the numerator.

None of the transformations known to the authors provides a satisfactory solution to this problem and in some cases (arc sine transformation) the transformation results in important changes in the observed relationship between variables. For this reason, all of the analyses of variance appearing in this report were performed on raw scores. In view of the circumstances cited above, however, it seems reasonable to state that any set of vigilance data that yields significant results probably represents a more powerful effect than the statistics would indicate.

Table B-1

Analysis of Variance for Multiple and Single Monitoring[a]

Source	SS	df	MS	F	p
Multiple vs. single	136.30	1	136.30	7.92	<.01
Subjects in same group	447.26	26	17.20		
Total	583.56	27			
Trials	61.30	2	30.96	9.14	<.01
Trials x conditions	23.17	2	11.58	3.42	<.05
Pooled subjects x trials	176.24	52	3.39		
Total	260.71	56			
	844.27	83			

[a]Figure 2 shows percentages of correct detections.

Table B-2

Analysis of Variance for Isolated Monitors and Monitors Who Worked in Pairs[a]

Source	SS	df	MS	F	p
Paired vs. isolated	42.86	1	42.86	2.11	.20 > p > .10
Subjects in same group	528.64	26	20.33		
Total	571.50	27			
Trials	93.02	2	46.51	11.07	< .005
Trials x conditions	9.23	2	4.62		
Pooled subjects x trials	218.49	52	4.20		
Total	320.74	56			
	892.24	83			

[a]Figure 3 shows percentages of correct detections.

Table B-3

Analysis of Variance for Differential-Treatments Session of Monetary Incentives Experiment[a]

Source	SS	df	MS	F	p
Reward vs. control	0.68	1	0.680	–	
Subjects in same group	83.98	38	2.210		
Total	84.66	39			
Trials	18.88	2	9.440	12.15	< .01
Trials x conditions	9.39	2	4.695	6.04	< .01
Pooled subjects x trials	59.07	76	0.777		
Total	87.34	80			
	172.00	119			

[a]Figure 11 shows percentages of correct detections.

Table B-4

Analysis of Variance for Identical-Treatment Session of Monetary Incentives Experiment[a]

Source	SS	df	MS	F	p
Reward vs. control	7.50	1	7.500	–	
Subjects in same group	330.46	38	8.696		
Total	337.96	39			
Trials	22.03	2	11.015	7.35	< .01
Trials x conditions	13.47	2	6.735	4.50	< .05
Pooled subjects x trials	113.84	76	1.498		
Total	149.34	80			
	487.30	119			

[a]Figure 12 shows percentages of correct detections.

Table B-5

Analysis of Variance of Correct Detections of True Signals[a]

Source	SS	df	MS	F	p
Conditions	16	3	5.33	–	
Subjects in same group	1,302	76	17.13		
Total	1,318	79			
Trials	84	4	21.00	12.21	<.01
Trials x conditions	5	12	0.42	–	
Pooled subjects x trials	523	304	1.72		
Total	612	320			
	1,930	399			

[a]Figure 13 shows percentages of correct detections of true signals.

Table B-6

Analysis of Variance for Experiment Involving Knowledge of Vigil Length[a]

Source	SS	df	MS	F	p
Conditions	20	1	20.00	–	
Subjects in same group	606	38	15.94		
Total	626	39			
Trials	43	4	10.75	5.91	<.01
Trials x conditions	12	4	3.00	1.65	
Pooled subjects x trials	277	152	1.82		
Total	332	160			
	958	199			

[a]Figure 14 shows percentages of correct detections.

Table B-7

Analysis of Variance for Experiment Involving Knowledge of Pretest Performance[a]

Source	SS	df	MS	F	p
Conditions	6	1	6.00	–	
Subjects in same group	644	38	16.95		
Total	650	39			
Trials	33	4	8.25	5.16	<.01
Trials x conditions	4	4	1.00		
Pooled subjects x trials	243	152	1.60		
Total	280	160			
	930	199			

[a]Figure 15 shows percentages of correct detections.

Table B-8

Analysis of Variance for Supervised Monitoring Experiment[a]

Source	SS	*df*	MS	*F*	*p*
Conditions	158	1	158.00	14.55	<.01
Subjects in same group	304	28	10.86		
Total	462	29			
Trials	90	4	22.50	16.19	<.01
Trials x conditions	12	4	3.00	2.16	
Pooled subjects x trials	156	112	1.39		
Total	258	120			
	720	149			

[a]Figure 16 shows percentages of correct detections.

Table B-9

Analysis of Variance for Optimization Experiment[a]

Source	SS	*df*	MS	*F*	*p*
Conditions	17	3	5.67	2.08	
Subjects in same group	98	36	2.72		
Total	115	39			
Trials	5	3	1.67	2.93	<.05
Trials x conditions	2	9	0.22		
Pooled subjects x trials	62	108	0.57		
Total	69	120			
	184	159			

[a]Figure 17 shows percentages of correct detections.

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Human Resources Research Office, George Washington U., Alexandria, Va.

VIGILANCE PERFORMANCE AS A FUNCTION OF TASK AND ENVIRONMENTAL VARIABLES, by Bruce O. Bergum and Donald J. Lehr

May 63, 40 p. incl. illus. tables, 7 refs. (Research Report 11) (Contract DA 44-188-ARO-2) DA Proj 2J024701A712 Unclassified Report

Experiments were conducted to compare the effects on vigilance of paired monitoring, high and low signal rates, rest periods, knowledge of pretest performance and of monitoring scores, rewards, supervision, and false signals. A final study compared four combinations of the three most effective variables—multiple monitoring, rest periods, and supervision. The results suggest that significantly high levels of performance can be maintained over fairly extended time periods, with careful selection of conditions.

UNCLASSIFIED

1. Behavior—vigilance
2. Military training—guided missile personnel
3. Guided missile detection—vigilance
4. Vigilance—radar tracking

I. Bergum, Bruce O., and Lehr, Donald J.
II. U.S. Army Air Defense Human Research Unit, Fort Bliss, Texas
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